# The Song Sparrow as a Biosentinel for Methylmercury in Riparian Food Webs of the San Francisco Bay Area

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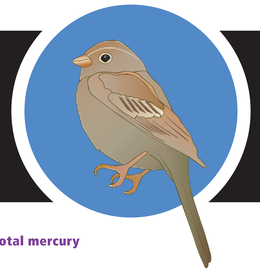


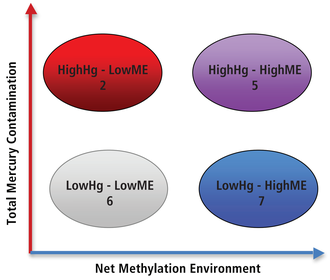
## INTRODUCTION

Recent studies in the San Francisco Bay Area and elsewhere have documented unexpectedly high concentrations of methylmercury in invertebrate-eating wildlife, such as songbirds, in wetland and riparian habitats. Under the guidance of a group of local and national experts, the Song Sparrow (*Melospiza melodia*) was determined to be the best riparian biosentinel candidate on the basis of its natural history, sampling feasibility, and distribution in local watersheds.

This project sampled Song Sparrows in riparian habitat throughout the Bay Area in order to assess the ability of this biosentinel to indicate relative mercury risk in riparian food webs. Sampling sites were chosen based on a conceptual model in which the key drivers of biosentinel exposure were 1) total mercury contamination of sediment and 2) aspects of the physical and chemical environment that affected net methylation of mercury (**Figure 1**).

**Figure 1. Conceptual Model for Site Selection**

Sites were selected based on this conceptual model, which identifies total mercury contamination and methylating environment as the key factors governing bioaccumulation of methylmercury in the riparian food web. The number of sites sampled is shown for each conceptual model category.



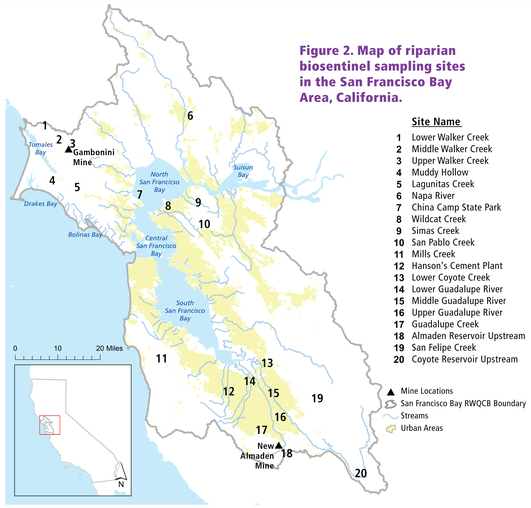




**Figure 2. Map of riparian biosentinel sampling sites in the San Francisco Bay Area, California.**

**Site Name**

1 Lower Walker Creek
2 Middle Walker Creek
3 Upper Walker Creek
4 Muddy Hollow
5 Lagunitas Creek
6 Napa River
7 China Camp State Park
8 Wildcat Creek
9 Simas Creek
10 San Pablo Creek
11 Mills Creek
12 Hanson's Cement Plant
13 Lower Coyote Creek
14 Lower Guadalupe River
15 Middle Guadalupe River
16 Upper Guadalupe River
17 Guadalupe Creek
18 Almaden Reservoir Upstream
19 San Felipe Creek
20 Coyote Reservoir Upstream

▲ Mine Locations
San Francisco Bay RWQCB Boundary
Streams
Urban Areas

**Table 1. Site attributes used for determining Total Mercury Contamination and Net Methylation Environment categories.**

| Conceptual Model Driver | Attributes | Criteria | Data Sources |
|---|---|---|---|
| Total Mercury Contamination (Hg)* | Direct measurement of total mercury in sediment | Sediment THg < 0.3 ppm dry = "LowHg"; Sediment THg > 1.0 ppm dry = "HighHg" | Sampling from this study, TMDL sampling, SF Bay Regional Water Board sampling, BMP Evaluation Report |
| | Legacy mercury mining pollution | Best professional judgement based on distance from mine, extent of contamination at mine site, and knowledge of watershed | Bay area mine locations from the 2006 San Francisco Bay Area Region Basin Plan |
| | Urbanization or industrial sources in watershed upstream | If population was less than 15,000 people = "LowHg" | 2000 Census data, ABAG 2000 Regional Existing Land Use dataset. |
| Net Methylation Environment (ME) | Septic tanks immediately upstream | If there were septic tanks within 500m upstream = "HighME" | Guadalupe River Mercury TMDL |
| | Known recent flooding | If flooding was known to have occurred within 8 months prior to sampling = "HighME" | Personal communication with land managers and regulators |
| | Wetland type | Sites near reservoir high-water line that had likely flooded during the previous year = "HighME" | National Hydrological Dataset (NHD) |
| | Presence of reservoir immediately upstream | If reservoir was present within 1km upstream = "HighME" | National Hydrological Dataset (NHD) |
| | Urbanization in watershed upstream | If population was >50,000 people = "HighME" | 2000 Census data |
| | Agriculture in watershed upstream | If > than 30% of land use was agriculture = "HighME" | ABAG 2000 Regional Existing Land Use dataset |

*Direct total mercury measurements were given higher priority than mining pollution, which was given higher priority than urbanization, in categorizing a site.

## METHODS

- Twenty riparian sites across the Bay Area were sampled (**Figure 2**).
- Sites were placed into conceptual model categories based on sediment total mercury data and landscape level indicators (**Table 1**).
- Birds were sampled during the breeding season, when Song Sparrows were territorial and sex and age could be identified more readily.
- Blood samples of 10-100 µl were collected by brachial veinipuncture.
- Avian blood samples were analyzed as wet weight for total mercury by the Trace Elements Lab at Texas A&M University.
- A general linear model was used to examine statistical differences in Song Sparrow blood total mercury by conceptual model category, sampling site, sex, and age.

## RESULTS

A total of 252 birds from 26 species were sampled. Song Sparrows were the most frequently sampled species (n=140), with blood mercury concentrations in Song Sparrows spanning more than two orders of magnitude (**Figure 3**). Average mercury concentrations at two of the twenty sites sampled were above 0.4ppm (wet weight). A previous study modeling the relationship between mercury concentration and reproductive effects found that maternal mercury concentrations of 0.4ppm (wet weight) translated to a 5% reduction in breeding success in Carolina Wrens (Jackson *et al*., 2011). The highest mercury concentrations found in individuals in this Song Sparrow study were above 2.5ppm, a level associated with a 50% decline in breeding success (**Table 2**). Song Sparrow blood total mercury varied by conceptual model category ($F_{3,\ 139} = 49.72$, $p < 0.0001$), site ($F_{15,\ 139} = 16.38$, $p < 0.0001$), and sex ($F_{2,\ 139} = 3.33$, $p = 0.039$; **Figure 4**). Average blood mercury concentration varied by species (**Table 3**).

**Figure 3. Song Sparrow blood total mercury concentration by site**

Dotted line at 0.4 ppm indicates a modeled 5% reduction in reproductive success. Dashed line at 1.0 ppm indicates a modeled 15% reduction in reproductive success (Jackson et al., 2011). Points represent values from individual birds. Boxes represent the 25th to 75th percentiles, with median indicated as a solid line. The error bars represent the 10th and 90th percentiles. Numbers above boxes are the sample size of birds sampled at each site.

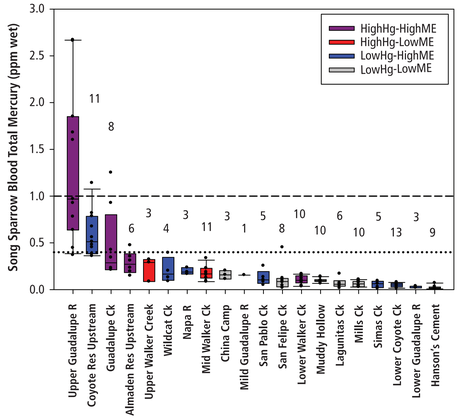



**Figure 4. The concentration of total mercury in Song Sparrow blood by conceptual model category**

Song Sparrows bioaccumulated the most mercury in sites characterized as high Total Mercury Contamination and High Net Methylation Environment. Points represent means at sites with three or more individuals. Boxes represent the 25th to 75th percentiles, with median indicated as a solid line. Numbers above boxes are the sample size of sites in each conceptual model category.

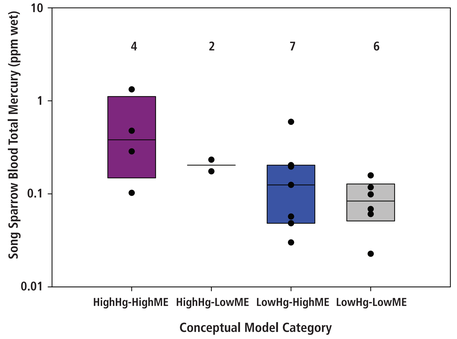



**Table 2. Blood total mercury concentrations in adult Song Sparrows and modeled reproductive effects from a MCestimate model of the reproductive effects of methylmercury in Carolina Wrens (Jackson et al. in prep).**

| Site Name | Mean THg (ppm) | Percent of Adults with THg Above 0.4 ppm* |
|---|---|---|
| Hanson's Cement Plant | 0.02 | 0 |
| Lower Guadalupe River | 0.03 | 0 |
| Mills Creek | 0.06 | 0 |
| Lower Coyote Creek | 0.06 | 0 |
| Simas Creek | 0.06 | 0 |
| Lagunitas Creek | 0.08 | 0 |
| Muddy Hollow | 0.09 | 0 |
| Lower Walker Creek | 0.11 | 0 |
| San Pablo Creek | 0.12 | 0 |
| Middle Guadalupe River | 0.16 | 0 |
| China Camp State Park | 0.16 | 0 |
| San Felipe Creek | 0.16 | 25% |
| Middle Walker Creek | 0.17 | 0 |
| Napa River | 0.20 | 0 |
| Wildcat Creek | 0.20 | 0 |
| Upper Walker Creek | 0.32 | 0 |
| Almaden Reservoir Upstream | 0.33 | 0 |
| Guadalupe Creek | 0.48 | 38% |
| Coyote Reservoir Upstream | 0.55 | 86% |
| Upper Guadalupe River | 1.64 | 100% |

Reproductive effects associated with total mercury concentrations: < 2%, 3-5%, 6-20%, >20%

* Model results indicate a reduction in breeding success of approximately 5%.

**Table 3. All bird species blood total mercury concentrations**

| Common Name | $N_{birds}$ | $N_{sites}$ | Mean THg (ppm) | SD |
|---|---|---|---|---|
| House Finch | 9 | 3 | 0.00 | 0.00 |
| Purple Finch | 7 | 3 | 0.01 | 0.01 |
| House Sparrow | 1 | 1 | 0.01 | - |
| American Goldfinch | 5 | 5 | 0.01 | 0.01 |
| Swainson's Thrush | 18 | 3 | 0.04 | 0.05 |
| California Towhee | 1 | 1 | 0.04 | - |
| Nuttall's Woodpecker | 2 | 2 | 0.06 | 0.06 |
| Spotted Towhee | 6 | 4 | 0.07 | 0.06 |
| Brown-headed Cowbird | 2 | 1 | 0.10 | 0.07 |
| Common Yellowthroat | 3 | 1 | 0.10 | 0.03 |
| House Wren | 1 | 1 | 0.11 | - |
| Steller's Jay | 1 | 1 | 0.11 | - |
| Chestnut-backed Chickadee | 8 | 5 | 0.13 | 0.13 |
| Black Phoebe | 3 | 3 | 0.15 | 0.08 |
| Bullock's Oriole | 3 | 1 | 0.15 | 0.02 |
| Orange-crowned Warbler | 9 | 4 | 0.16 | 0.05 |
| American Robin | 2 | 2 | 0.16 | 0.20 |
| Wrentit | 3 | 3 | 0.16 | 0.12 |
| Ash-throated Flycatcher | 2 | 1 | 0.17 | 0.01 |
| Oak Titmouse | 2 | 2 | 0.25 | 0.10 |
| Song Sparrow | 140 | 20 | 0.26 | 0.43 |
| Western Scrub-Jay | 3 | 2 | 0.28 | 0.44 |
| Wilson's Warbler | 5 | 2 | 0.37 | 0.23 |
| Bewick's Wren | 11 | 7 | 0.46 | 0.51 |
| Western Flycatcher | 5 | 5 | 0.51 | 0.27 |

## DISCUSSION

- Song Sparrows reflected differences in mercury risk between sites, demonstrating their value as a biosentinel species.
- Both total mercury contamination and net methylation environment were important factors in determining blood total mercury.
- Trends in methylmercury by species suggest that when Song Sparrow methylmercury is high other riparian species are likely also at risk.
- Mercury concentrations at the sites with the highest risk were associated with a substantial decline in reproductive success in songbirds, underscoring the need to understand and monitor methylmercury exposure in these systems.
- In stressed populations (many urbanized areas) there may be little to no surplus of young birds each year, which would amplify the consequences of reproductive loss through methylmercury effects.

## References

Jackson, AK, Condon, AM, Etterson, MA, Evers, DC, Folsom, SB, Detweiler, J, Schmerfeld, J, Cristol, DA. 2011. Modeling the effect of mercury exposure on the reproductive success of a free-living terrestrial songbird.

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